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BFKL PHYSICS IN JET PRODUCTION AT e^+e^- COLLIDERS*

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Virtual photon scattering in e^+e^- collisions can result in events with the electron-positron pair at large rapidity separation with hadronic activity in between. The BFKL equation resums large logarithms that dominate the cross section for this process. We report here on a Monte Carlo method for solving the BFKL equation that allows kinematic constraints to be taken into account and show results for e^+e^- collisions.

1. Leading-Order BFKL and Improved BFKL Monte Carlo

In the QCD description of hadronic processes there can appear logarithms that multiply each power of the strong coupling constant α_s, spoiling the utility of fixed order perturbation theory in the regions where these logarithms are large. The BFKL equation[1] resums large logarithms due to emission of multiple soft gluons (real and virtual) which are comparable in transverse momentum but strongly ordered in rapidity.

The BFKL equation can be solved analytically if there are no constraints (e.g. from kinematics) on the transverse momenta of emitted gluons. Clearly this requires giving up conservation of energy, and furthermore the implicit sum over arbitrary numbers of gluons gives a result with leading-order kinematics only. For purposes of comparison with experiment, a more realistic BFKL prediction would be better. This can be obtained[2,4] by solving the BFKL equation iteratively, making the gluon summation explicit. The result can be incorporated into a Monte Carlo event generator, allowing for kinematic constraints to be applied directly. The Monte Carlo approach has been applied to dijet production at large rapidity in hadron colliders and it improves the agreement between BFKL predictions and experiment[2].

2. Virtual Photon Scattering at e^+e^- Colliders

BFKL physics can be important in virtual photon scattering into hadrons at e^+e^- colliders when the electron and positron are scattered into the forward and backward regions ("double-tagged" events). BFKL effects are relevant in the region where the invariant mass W of the hadronic system is large and

$$s >> Q^2 >> \Lambda^2_{QCD},$$

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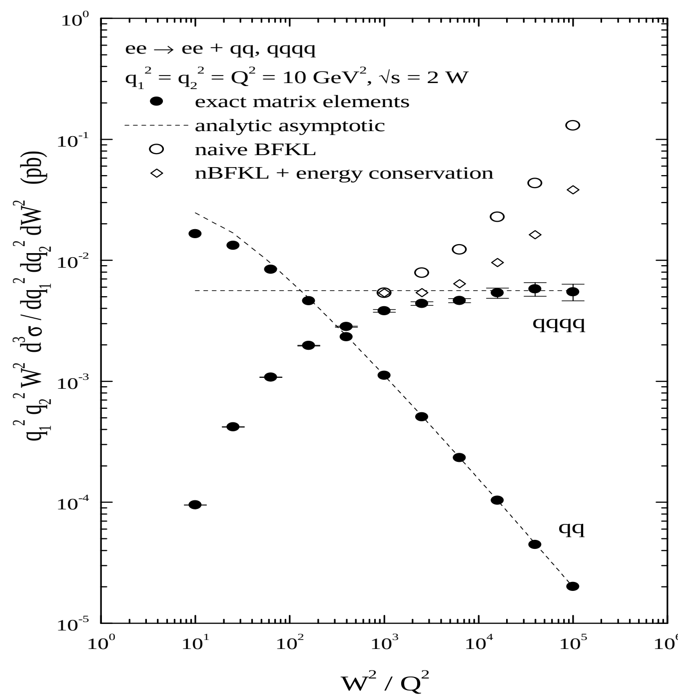

Figure 1: Exact (closed data points) and analytic asymptotic (dashed line) $e^+e^- \to e^+e^-q\bar{q}$ and $e^+e^- \to e^+e^-q\bar{q}q\bar{q}$ cross sections versus W^2/Q^2 at fixed $W^2/s = 1/4$. Also shown: analytic BFKL without (open circles) and with (open diamonds) energy conservation imposed.

where Q^2 is the photon virtuality and $\sqrt{s}$ is the total c.m. energy. The corresponding fixed-order QCD process is $\gamma^*\gamma^* \to q\bar{q}q\bar{q}$ via t-channel gluon exchange. The BFKL result is obtained by attaching a gluon ladder to the t-channel gluon.

Figure 1 compares the fixed-order QCD cross section with the naive (analytic) BFKL prediction. The cross section shown,

$$W^2 Q_1^2 Q_2^2 \, \frac{d^3\sigma}{dW^2 dQ_1^2 dQ_2^2}$$

as a function of W^2/Q^2 for fixed $\sqrt{s}/W$ approaches a constant in fixed-order QCD but the BFKL cross section (open circles) continues to rise. The improved BFKL Monte Carlo calculation will result in a slower rise; that calculation is in progress [3]but an upper limit can be obtained by imposing an upper limit on the gluon energies, as shown with open diamonds. It should be noted that the position in W^2/Q^2 where BFKL is matched to asymptotic QCD is arbitrary in leading order; our choice is reasonable but not fixed in the theory.

The L3 collaboration at LEP have measured the $\gamma^*\gamma^*$ cross section from couble-tagged e^+e^- events, and their result lies between asymptotic QCD (which is flat)

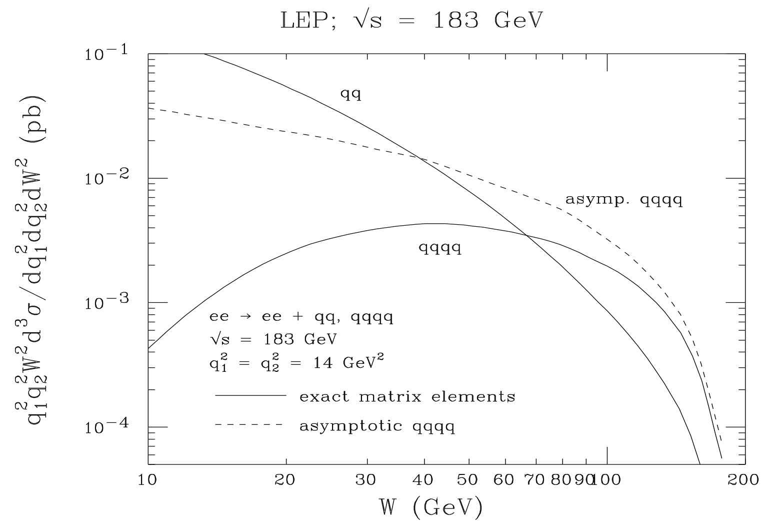

Figure 2: Exact (solid lines) and analytic asymptotic (dashed line) $e^+e^- \to e^+e^- q\bar{q}$ and $e^+e^- \to e^+e^- q\bar{q}q\bar{q}$ cross sections versus W^2/Q^2 at fixed $\sqrt{s} = 183$ GeV.

and analytic BFKL (which rises); see for example[5]. It is likely that the BFKL Monte Carlo prediction will lie closer to the data, but the QCD prediction itself deserves some scrutiny. Figure 2 compares the exact and asymptotic QCD predictions for the LEP energy $\sqrt{s} = 183$ GeV (this is the undivided e^+e^- cross section that includes the photon luminosity and is therefore not flat). The LEP measurements correspond to values of W in the range between about 15 and 90 GeV. We see from the figure that the QCD prediction is not close to its asymptotic limit, and the ratio of the two rises in this region, as do the data. Until the fixed-order QCD and BFKL Monte Carlo predictions are sorted out, it is not clear what we can conclude from the data. This work, at both LEP and linear collider energies, is currently in progress[3].

3. Acknowledgments

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